**PAPER ID: 11A06Q**

# 3D MODELING IN AUTOCAD® AS A BASIC COMPONENT OF THE INITIAL TRAINING OF MECHANICAL ENGINEERS

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### A R T I C L E I N F O

### A B S T R A C T

The design of engineering facilities is currently based on solid modeling methods. Development of design documentation is carried out in a semi-automatic mode based on the created models. The role and content of such disciplines as descriptive geometry and mechanical engineering drawing in the training of mechanical engineering specialists in this regard requires a significant rethinking. At the same time, according to the authors, when integrating with modern 3D technologies of these disciplines, their foundations should be preserved. The article is devoted to the integration of descriptive geometry and 3D-modeling methods in the educational process of training engineers in the field of machine-building.

**Disciplinary**: Engineering Education and Curriculum, Mechanical Engineering, Computer Graphics.

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## 1. INTRODUCTION

For many decades, one of the main disciplines of the system of training the highest technical qualifications (engineers of mechanics, engineers of builders and other specialists) is descriptive geometry. It was created more than two hundred years ago [1, 2] by the French scientist Gaspar Monge, "descriptive geometry was cultivated in the technical school as a science, without which it is inconceivable the formation of an engineer" [1]. As a rule, the "birth" of any product, practically regardless of the field of application, is associated with three stages: design and conceptualization of the idea in the engineer's mind, creation and processing of documentation, production of the product itself on the basis of this documentation. Obviously, these stages are not only closely interrelated, but they do not exhaust all the nuances of preparing and ensuring the production of the finished product. If the product is a construction, in reality a three-dimensional, then the second stage necessarily includes the presentation of information about this design in the form convenient for processing it. Currently, this is a three-dimensional computer model [3, 4, 5], the necessary calculations [6 – 12]

and drawing. Drawing, according to Monge, is the language of technology, and the grammar of this language is descriptive geometry [1].

The technology of creating 3D models of three-dimensional objects and the development of design documentation on their basis became available to students and teachers of universities in the early years of the 21st century. Currently, the design process carried out by the vast majority of enterprises is based on the following scheme: the creation of a 3D model of the product, the execution on its basis of calculations (kinematic, dynamic, strength and others), the development of the designed product on their basis and, in a semi-automatic mode, the development drawings and other documentation necessary for the subsequent organization of his (product) production. At first glance, with such an approach, the knowledge of many disciplines studied in higher education institutions is not necessary. The authors may exaggerate, but among such disciplines, mathematics – numbers can be multiplied on a calculator, and, for example, solving an equation in Maple, MatLAB or MathCAD, mechanics – problems in the theory of mechanisms and machines, machine parts, material resistance are easily solved in within the framework of many 3D modeling systems: Autodesk Inventor Professional, Autodesk Simulation, SolidWorks, descriptive geometry – for example, the line of intersection of geometric objects can be constructed without difficulty in any of the three-dimensional modeling systems. However, the essence of higher education, according to the authors, is not the acquisition of a set of skills and the ability to use them mechanically, but the formation of an engineer's special structure of thinking and knowledge base in a whole range of sciences that allowhim to creatively approach the task assigned to him, just copy, but get the best possible solution.

## 2. "DESCRIPTIVE GEOMETRY" IN THE EDUCATIONAL PROCESS

This article material is associated with the graphic preparation of students in discipline descriptive geometry, described in [3, 4, 5]. As noted above, descriptive geometry, being one of the basic disciplines that form the ability of an engineer to work with 3D geometric objects, both mentally and on a plane, cannot and should not distance himself from modern computer 3D technologies. For several years, the authors have been developing and testing a methodology for preparing students, which the framework of the standard course of descriptive geometry:

- to teach students practical skills in graphical works using the Autodesk AutoCAD program;
- to form basic concepts about methods and tasks of discipline descriptive geometry;
- to master the practical skills of applying computer 3D modeling methods for solving typical tasks of descriptive geometry.

It is three tasks, different in its nature, content and laboriousness. Their decision, with a minimum of time costs (1 hour of lectures and 1 or 2 hours of practice per week for 17 weeks of the first semester), requires the availability of comprehensive guidelines and the availability of appropriate software. Students are trained on the basis of Autodesk software products [3, 4, 5], in this case Autodesk AutoCAD.
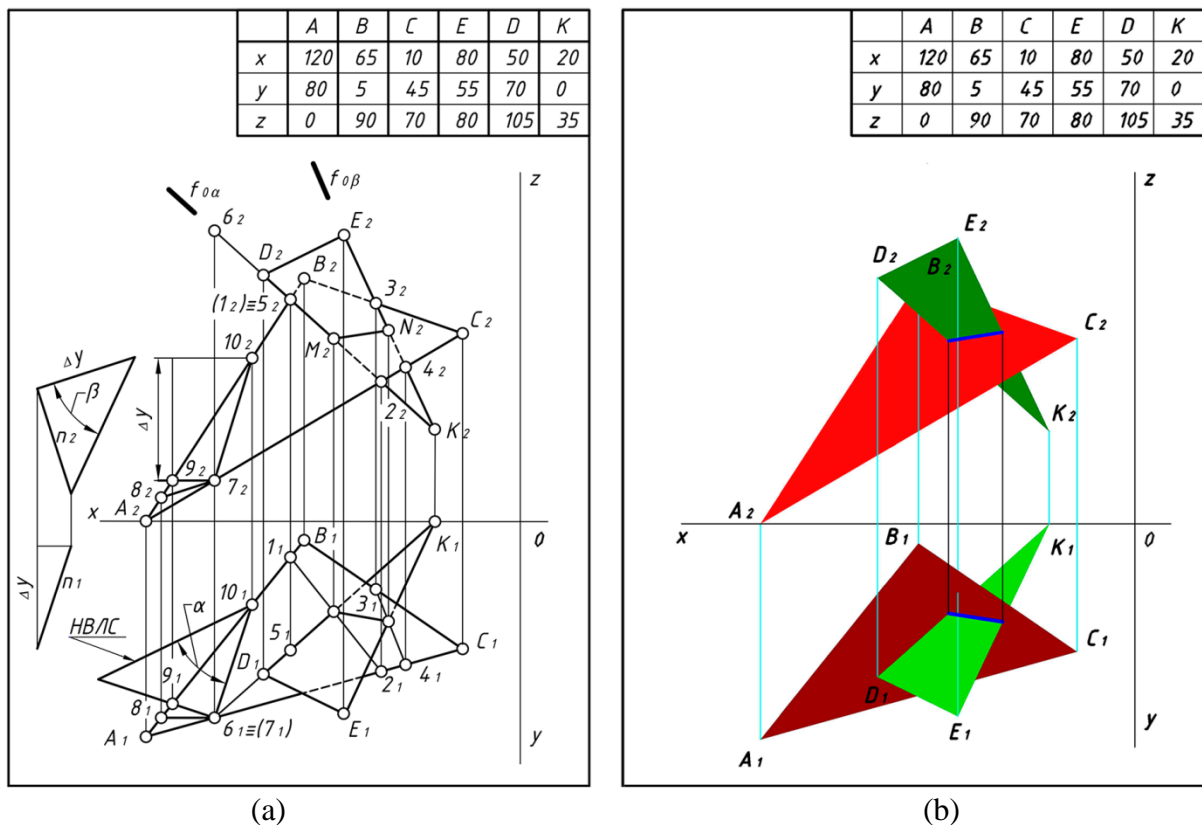
## 3. STRUCTURE OF DESCRIPTIVE GEOMETRY COURSE

Conditionally, the content of the course can be divided into three parts: work in Autodesk AutoCAD, study of theoretical and practical methods of descriptive geometry, acquisition of 3D modeling methods for solving practical problems of descriptive geometry.

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The first and second parts of the course in the first six weeks of training are combined in time. During this period, practical classes of 80 percent are devoted to the development of the AutoCAD system, the theoretical material of the course is studied during lectures, in part, in practical classes and independently. The way of control at this stage of training: the execution of test tasks in testing systems. There is one self-dependent work. Topics – projection methods, drawings of a point and a line segment. The practical result of mastering the first part of the discipline is the acquisition of skills for performing flat drawings in AutoCAD. The practical component of the second part of the course and the third part of it is combined in time. Approximately this stage of preparation of students begins with the 7th week of training and lasts for 10 weeks before the end of the semester.
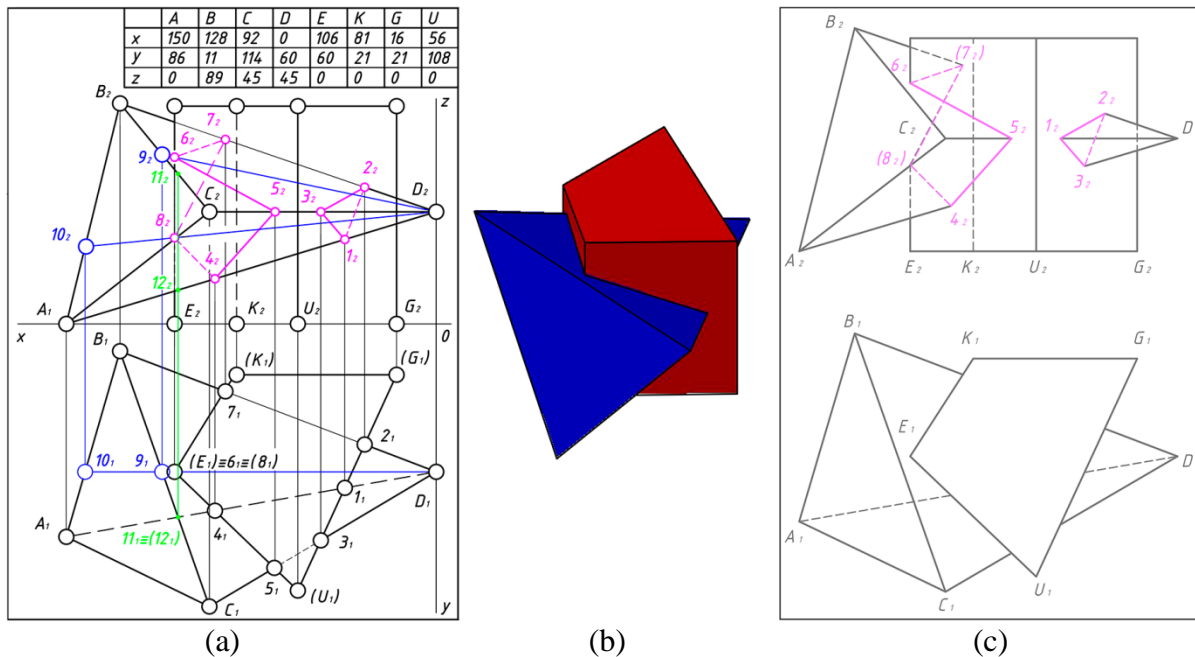
## 4. CONTENT OF DESCRIPTIVE GEOMETRY COURSE

**Individual task №1**. Draw the intersection line of two general planes defined by triangles. Determine the inclination angles of these planes to the projection planes. Define visibility. Solution methods: traditional (the method of cutting planes) and 3D modeling in Autodesk AutoCAD. The image of the 3D model is built in the model space. When building, 3D editing commands are used. The results of the work are shown in Figure 1.

**Individual task №2**. Draw the intersection line of the polyhedrons. The construction of the flat patterns, the production of the physical model of the projected body, is glued from the paper on the basis of the flat pattern. Methods of solution: traditional (descriptive geometry) and 3D-modeling. The results of the work are shown in Figure 2.



|   | A | B | C | E | D | K |
|---|---|---|---|---|---|---|
| x | 120 | 65 | 10 | 80 | 50 | 20 |
| y | 80 | 5 | 45 | 55 | 70 | 0 |
| z | 0 | 90 | 70 | 80 | 105 | 35 |

|   | A | B | C | E | D | K |
|---|---|---|---|---|---|---|
| x | 120 | 65 | 10 | 80 | 50 | 20 |
| y | 80 | 5 | 45 | 55 | 70 | 0 |
| z | 0 | 90 | 70 | 80 | 105 | 35 |

(a)                                         (b)

**Figure 1**: Plane in general position: plotting the line of intersection of planes using the methods of descriptive geometry (a) and 3D modeling (b).

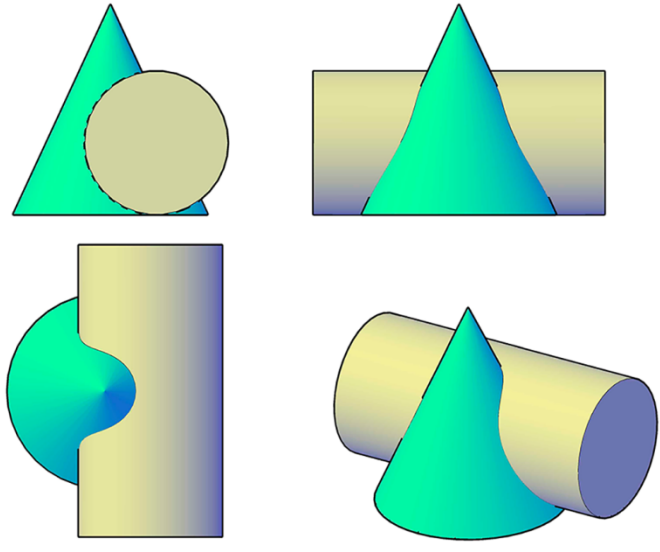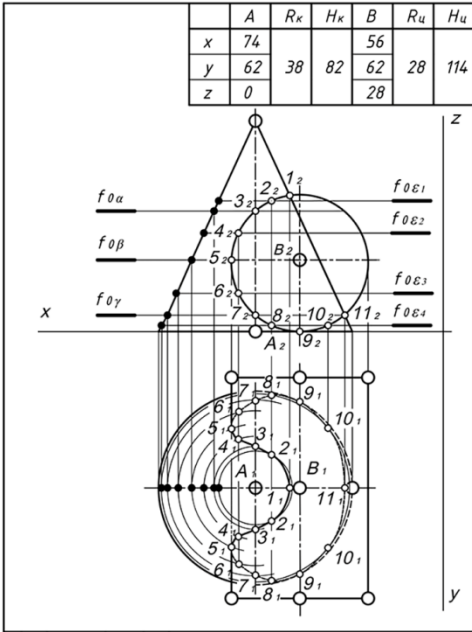| | A | B | C | D | E | K | G | U |
|---|---|---|---|---|---|---|---|---|
| x | 150 | 128 | 92 | 0 | 106 | 81 | 16 | 56 |
| y | 86 | 11 | 114 | 60 | 60 | 21 | 21 | 108 |
| z | 0 | 89 | 45 | 45 | 0 | 0 | 0 | 0 |

**Figure 2**: Polyhedron draw intersection line by methods of
(a) descriptive geometry and (b) 3D modeling in the space of model and (c) sheet.

To build up the flat pattern of pyramid and prism 3D methods are used. One of the ways is sequential placement of the polyhedron faces in the plane of the screen (model space), then the construction of the base view in sheet space and the stroke of faces. The flat images obtained in sheet space of the sheet are combined along common faces into a single image of the sweep. The result is not informative, so in Figure 2 it is not given.

**Individual task № 3**. Draw a line of intersection of the surfaces of revolution. Task № 3 is similar to task №2. Difference: the construction of the flat pattern is carried out using the methods of descriptive geometry. The results of the work are shown in Figure 3.
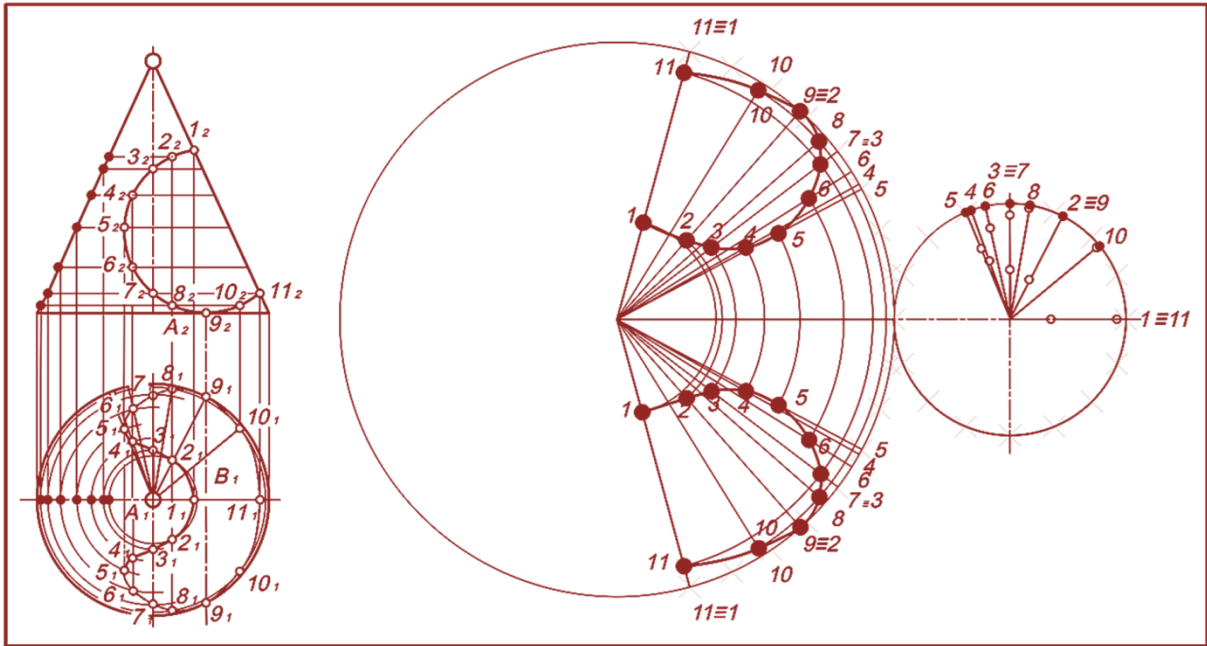
Any rather complicated construction, which is the object of the professional activity of an engineer, this is most often the result of performing Boolean operations on three-dimensional bodies, which include the simplest (point, straight, plane) and more complex geometric images – the curved line, the surface and the body.

Figure 4 shows the front section of the product and its three-dimensional model. Probably one of the main tasks of descriptive geometry is to learn how to see in the image not a set of lines, but the result of combining three cylindrical surfaces with two conical surfaces and one torus with the subsequent subtraction of the surfaces of two conical, one cylindrical (hole) and screw (thread). The ability to work with three-dimensional structures in this way is one of the most important features that distinguish a professional engineer from the corresponding theoretical training.
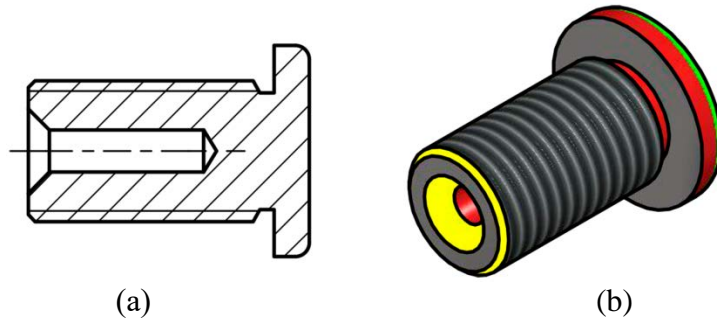
|   | A | $R_к$ | $H_к$ | B | $R_ц$ | $H_ц$ |
|---|---|---|---|---|---|---|
| x | 74 |  |  | 56 |  |  |
| y | 62 | 38 | 82 | 62 | 28 | 114 |
| z | 0 |  |  | 28 |  |  |

(a)

(b)

(c)

**Figure 3**: Surfaces of revolution: draw intersection line by methods of descriptive geometry (a), 3D modeling in model space (b), and constructing a cone scan (c).



(a)                                    (b)

**Figure 4**: Representation of a complex object: (a) a drawing (b) a 3D model.

## 5. CONCLUSION

This article articulates the basic teaching of descriptive geometry via the use of Autodesk AutoCAD software as a learning tool. This is mechanical engineering 3D drawings help students in trainings of mechanical engineering and related disciplines to better apprehend the subject through visualization of the created models. Many vital complex computer graphic examples are included in this articles, from drawings to 3D models.

## 6. AVAILABILITY OF DATA AND MATERIAL

No data is generated from this study.

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